LONG-TERM MONITORING PROTOCOLS FOR NEW AND UPGRADED HYDROPOWER PROJECTS IN BRITISH COLUMBIA AND YUKON TERRITORY

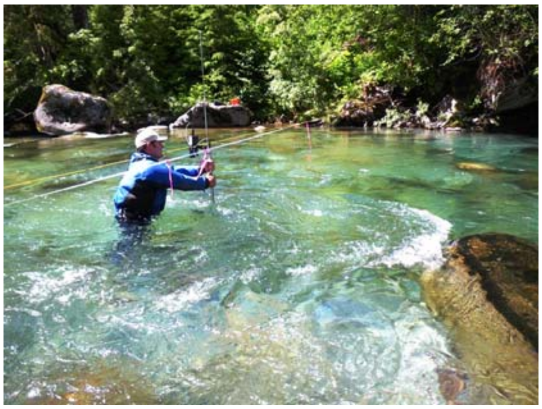

Figure 1: Measuring flow. Photo with permission of Adam Lewis, Ecofish Research Ltd.

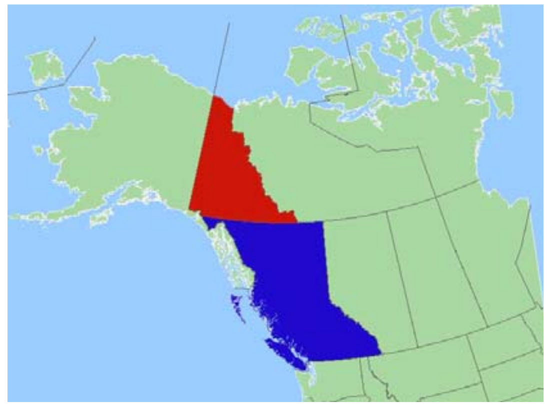

Figure 2. DFO's Pacific Region includes the Yukon Territory and British Columbia

Context

Fisheries and Oceans Canada (DFO) Ecosystem Management Branch, Pacific Region (British Columbia and Yukon Territory), requested science advice to inform the development of standardized habitat monitoring protocols for new and upgraded hydropower projects in British Columbia and Yukon Territory. The purpose of the protocols is to evaluate the effects of these projects on fish and fish habitat. Science advice was sought to assist with establishing the parameters and types of monitoring necessary for long-term monitoring of new Hydropower projects, as well as those undergoing significant upgrades. They are intended to apply to most run-of-river hydropower projects involving streams or lakes, as well as projects that involve the creation of a storage reservoir.

Hydropower development proposals currently represent the largest number of referrals to DFO's Habitat Management Program in the Pacific Region. Standardized monitoring protocols will result in consistency in the requirements for project proponents, will promote continuity in data collection methods over time, and will permit results to be compared among projects in order to assess environmental trends over time and space. These protocols also will measure Program success based on the effectiveness of mitigation and compensation activities, and the contribution of regulatory and non-regulatory activities to support continuous Program improvement and future decision making. This is aligned with the National Habitat Management Program, whereby monitoring results are to be used to evaluate, modify and improve Program delivery. The development of scientifically defensible monitoring methodologies will directly support the departmental priority of performance measurement and quality of service to Canadians.

This Science Advisory Report has resulted from a Fisheries and Oceans Canada, Canadian Science Advisory Secretariat Pacific Regional Science Advisory Process. Additional publications resulting from this process will be posted as they become available on the DFO Science Advisory Schedule at http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

SUMMARY

- The primary objectives of the protocols are to evaluate the effectiveness of mitigation and compensation activities, and the effects of the project on fish and fish habitat.
- Some of the potential impacts of these types of projects are not well understood and more focused research may be needed in order to develop additional protocols to monitor specific effects. Examples include the effects of rapid flow fluctuations (and ramping rates) and changes to winter flows and ice conditions.
- The components of the protocols were found to be generally acceptable for smaller projects on streams, but limitations were identified for those associated with larger rivers and reservoirs.
- The protocols are only intended to monitor the effects of the project itself, and not cumulative effects associated with the project and other activities or projects.
- The protocols suggest the use of a Before-After Control-Impact design, but there can be difficulties and shortcomings to this approach and alternative designs may need to be considered.
- The need to collect baseline data for as long as possible prior to construction is emphasized, in order to accurately represent pre-development conditions.
- The protocols may not have sufficient statistical power to detect small changes to the ecosystem.
- Monitoring results based on these protocols should be reviewed in 5-10 years so that the protocols can be modified as appropriate.

INTRODUCTION

DFO regulates activities under the authority of the *Fisheries Act* to prevent obstructions to fish passage (*s.* 20), to ensure sufficient flows for fish (*s.* 22), to prevent the killing of fish by means other than fishing (*s.* 32), and to prevent the harmful alteration, disruption or destruction (HADD) of fish habitat (*s.* 35). Monitoring is an important component of DFO's regulatory program and is required of most projects as a condition for Authorization. Monitoring is used to confirm compliance with regulatory requirements and to assess whether those requirements are achieving desired environmental outcomes. Under the *Species at Risk Act*, projects that may affect listed wildlife species or their critical habitat must adopt measures to avoid or lessen adverse effects, and monitoring is required to evaluate those effects..

Hydropower development proposals currently represent the largest number of referrals (requests for project review to determine compliance with the *Fisheries Act*) to the Habitat Management Program in the Pacific Region. To date, monitoring requirements have been inconsistent among projects. Standardized monitoring methodologies will create consistency in the requirements of project proponents and allow for the comparison of data across multiple projects to evaluate environmental effects and generalize results across projects, as well as to evaluate success of the Habitat Management Program.

Rationale for Assessment

DFO Habitat Management Program requested science advice to inform the development of standardized habitat monitoring protocols for new and upgraded hydropower projects in British Columbia and Yukon Territory. The purpose of the monitoring protocols is to establish the parameters and types of monitoring necessary for the effective long-term monitoring of new hydropower projects, as well as those undergoing significant upgrades. They are intended to apply to most run-of-river hydropower projects involving streams or lakes, as well as projects that involve the creation of storage reservoirs.

ASSESSMENT

DFO has identified three types of monitoring (compliance, effectiveness, and response monitoring) that may be required of hydropower projects. Compliance monitoring determines whether the construction and operation of the project complies with the conditions of its Fisheries Act Authorization. Effectiveness monitoring is designed to evaluate whether compensation and mitigation requirements of the Authorization have been effective. Response monitoring is designed to evaluate the overall impact of the project on fish and fish habitat. The goals of response monitoring are two-fold: first, to determine if project impacts match with predictions stated in the Environmental Impact Assessment (EIA) under CEAA (*Canadian Environmental Assessment Act*) and in *Fisheries Act* Authorizations; and second, to facilitate corporate learning for similar future projects. Response monitoring is the most difficult of the three to design and implement.

Ecofish Research Ltd. and Solander Ecological Research were commissioned by DFO to develop a working paper, based on recent experience, accepted scientific methods and established guidelines, that outlines appropriate monitoring protocols and provides guidance on the selection of parameters, methods and standards for monitoring for effective long-term monitoring of new hydropower projects, as well as those undergoing significant upgrades. That document and the subsequent Canadian Science Advisory Secretariat (CSAS) Regional Advisory Process informs this CSAS Science Advisory Report.

Monitoring Program Design

Impacts from hydropower projects are classified as footprint or operational impacts. Footprint impacts are permanent and are caused by the project infrastructure. These are generally dealt with using standard habitat management procedures. Operational impacts are those associated with the operation of the project and could be potentially mitigated by changes to the way the facility is operated, or by modification of the physical works. For run-of-river hydropower projects there are two principal types of operational impacts on aquatic habitats: those that occur within the diversion reach below the dam or weir, and those downstream of the power plant.

The basis of any effective monitoring program is a study design that permits the detection of changes resulting from the operation of the facility. The before-after control-impact (BACI) experimental design is considered a rigorous approach for monitoring changes in aquatic habitats (Schmitt and Osenberg 1996; Pearson *et al.* 2005). At least two years of data need to be collected pre-commissioning (baseline data) at both the project site and unaffected, but comparable habitats. The unaffected (control) site is used to control for regional effects (such as climate) on monitoring metrics that could potentially confound the interpretation of data collected at the project site. Finding comparable habitats to use as control sites is often challenging. Projects with complex environmental issues, valuable habitats or high variability will require longer baseline characterization.

Other approaches can be used instead of the BACI design, but these can be less powerful (Schmitt and Osenberg 1996). Options include the before-after (BA) design, which is appropriate if the effects of the project can be separated from (or are not affected by) long-term or region-wide environmental factors. The BA design is also used when a suitable control site cannot be found. A spatial design or reference approach can be used if pre-project baseline data are not available. The spatial design (also known as a control-impact design) compares metrics from the project site after commissioning to those from a number of unaffected control sites. The reference approach compares metrics from the project site to “reference” or regional norms or standards. Water quality is one area where metrics may be compared to regional or national standards (e.g., dissolved oxygen, temperature). These approaches have to be used for compensation works if new habitats are created and no baseline data collection is possible.

The baseline characterization of the environment should be implemented as soon as possible, e.g., during the first year of the EIA. After construction, monitoring should continue for several years with the same methods, sites and timing of sampling. EIA and monitoring programs are thus integrated and consistent to provide a more efficient, comparable, and thus more statistically powerful assessment.

The proposed protocols outline methods for measuring parameters that are appropriate for response monitoring for the project but may not be useful for cumulative effects monitoring at the watershed scale. These include physical parameters, such as water quality, water temperature, fish habitat, and stream morphology; as well as biotic parameters relating to the invertebrate, fish and wildlife communities present. Recommended sample sizes are provided based on a power analysis assuming the following: coefficient of variation in samples = 50%, alpha = 0.05, power = 0.8, effect size = 50% (Hatfield et al. 2007). The recommended number of sites, sites sampled per year, and years of sampling should be considered the minimum acceptable level of effort as managers are likely to be more interested in smaller effect sizes than a 50% change.

Sources of Uncertainty

Although most of the protocols are based on standard stream and lake sampling techniques, there is uncertainty about whether they will be sufficiently powerful to detect small changes, particularly to biological metrics that are inherently highly variable. There is also uncertainty about whether suitable control sites can be found for some projects, which may result in the use of some of the less powerful sampling designs.

CONCLUSIONS AND ADVICE

The proposed protocols are intended to apply to most run-of-river hydropower projects involving streams or lakes, as well as projects that involve the creation of a storage reservoir. Projects with a generating capacity of > 200 MW, or with a reservoir surface area that would exceed the natural annual mean surface area by 1500 ha or more, will likely have site-specific monitoring needs scaled to the larger ecosystems affected. The number of components and the magnitude of sampling effort will vary with the specific project layout, environmental characteristics, and the type and importance of the biota present. Detecting effects and sorting out the role of the hydropower project on changes to biota relative to other sources of variation will be challenging because the residual impacts on fish populations and habitats may be small and these systems are often inherently highly variable.

Proposed parameters and methods necessary for effective monitoring of new and upgraded hydropower projects were considered to be appropriate. The level of sampling specified in the protocols should be considered a minimum and managers are advised that the ability to detect small or moderate environmental effects may be limited. For example, the recommended fish monitoring protocols may be able to detect large (>50%) changes in fish populations but may not be powerful enough for smaller but potentially important changes. Since one goal of response monitoring is to evaluate Habitat Management’s No-Net-Loss (NNL) guiding principle and its requirement for compensation and mitigation to minimize impacts to fish and habitat, the residual impact to habitats is expected to result in a biotic response far smaller than a 50% decrease. Thus the protocols for biotic response monitoring within the guidelines may result in ambiguous results (see Bradford et al. 2005) because the duration and intensity of the monitoring may be too small to overcome the combined effects of sampling and environmental variability.

While the proposed protocols are generally endorsed, several additional limitations and situations that may require modifications to a site-specific monitoring plan were identified:

- The monitoring of fish stranding due to flow changes and the development of guidelines for ramping is an area of active investigation. Previously developed protocols and guidelines are based on studies from large alluvial rivers (Hunter 1992), and are guided by natural rates of stage change observed in unregulated rivers. These may not be relevant to smaller, steeper streams used for run-of-river hydropower. The protocols provide some guidance for the design of ramping studies, however, it is recommended that the issue be reevaluated in the next few years, as more local experience is gained.
- The utility of monitoring invertebrates as a measure of ecosystem response to flow alteration is an area of emerging science (e.g. Armanini et al. 2011). The protocols provide only limited direction on appropriate protocols for invertebrate sampling. Given the high cost of sample processing, particularly invertebrate identification, and high variability in the data (Miller *et al*. 2010) it is recommended that the design of monitoring protocols for invertebrates be done on a case-by-case basis, and with a clear expectation of how the information will be used.
- The monitoring protocols provide minimal direction on the monitoring of small headwater ponds or reservoirs and further protocol development may be required. The guidelines are inadequate for monitoring large reservoirs; in these cases, system-specific protocols are likely to be developed.
- These monitoring protocols do not adequately evaluate the effects of altered flow regimes on ice conditions, and the effects of ice on stream biota. Further sampling design and research in this area is necessary.
- While electrofishing has been identified as a sampling method, its use can be restricted in some circumstances. The implications of removing this method from the suite of sampling tools for small streams may be significant and could undermine the utility of some sampling designs.
- There are gaps in the understanding of hydrology in small, steep streams in BC and the Yukon. While it is possible to develop estimates of streamflow for some systems with proxy information and less than two years of data collection, the provisional protocols of two years of data collection is recommended as a general protocol and is consistent with the existing Provincial requirement.
- The recommended fish monitoring protocols are designed to detect large changes (i.e. >50%) in fish populations systems, but may not be sensitive enough to detect smaller effects. If managers wish to detect <50 % change in fish abundance or if species with low abundances are present, considerably more effort and a site specific sampling design will be necessary.
- A pre-project baseline monitoring period of 2 years is proposed, but it should be recognized that this is the absolute minimum to allow for a Before-After comparison. Baseline monitoring (even if the program is skeletal) should begin as soon as possible

and should continue through the construction phase to allow for a sufficient baseline dataset.

- The protocols do not address watershed-level cumulative impacts that may occur when there are multiple projects or activities in a catchment. These will require further research, and could involve the development of ecosystem health indicators.

Given the relatively short history of monitoring run-of-the river type projects, it is recommended that these protocols be reviewed in approximately 5 to 10 years, once sufficient data have accumulated. At that point the utility of the sampling protocols, the design of the program, and the spatial and temporal intensity of sampling can be reviewed. New developments in data analysis and interpretation should also be reviewed as methods such as Bayesian analysis, Fuzzy logic, and decision theory will likely replace classical statistical approaches to interpretation of environmental assessment information.

SOURCES OF INFORMATION

This Science Advisory Report has resulted from a Fisheries and Oceans Canada, Canadian Science Advisory Pacific workshop, June 20-21, 2011 on long-term monitoring protocols for new and upgraded hydropower projects in British Columbia and Yukon Territory. Additional publications from this process will be posted as they become available on the DFO Science Advisory Schedule at http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

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